

ESTABLISHMENT OF *UROPHORA SIRUNASEVA* (HERING) (DIPTERA: TEPHRITIDAE) FOR BIOLOGICAL CONTROL OF YELLOW STARThISTLE IN THE WESTERN UNITED STATES

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Abstract.—*Urophora sirunaseva* (Hering) (Diptera: Tephritidae) is a capitulum-galling natural enemy of yellow starthistle, *Centaurea solstitialis* (Asteraceae). The fly was first introduced into the United States for biological control of yellow starthistle in the mid-1980s. As of 1992, field establishment of *U. sirunaseva* is known from California (five sites), Oregon (six sites), and Washington (one site). Field sample data for four populations of *U. sirunaseva* from California and Oregon in 1992 yielded a range of galled host capitula from 22.1 to 44.0%, and a range of mean galls per galled capitulum from 1.8 to 2.1.

Key Words.—Insecta, gall, biological control, weed, *Urophora*, *Centaurea*

Yellow starthistle (*Centaurea solstitialis* L., Asteraceae) is an Eurasian annual that is a highly invasive, naturalized weed of grasslands and other environments in the western United States, especially in California ($\approx 3,200,000$ ha infested), Idaho ($\approx 81,000$ ha infested), Oregon ($\approx 400,000$ ha infested), and Washington ($\approx 54,000$ ha infested) (Maddox & Mayfield 1985, Maddox et al. 1985, Roché & Roché 1988, Callihan et al. 1989, Turner et al. in press). The weed displaces native and other more desirable plants, the spiny capitula deter grazing by livestock and are a nuisance to people working or recreating on infested lands, and it is poisonous to horses (Cordy 1978).

Urophora sirunaseva (Hering) (Diptera: Tephritidae) is a natural enemy of yellow starthistle from Greece eastwards (White & Clement 1987). *Urophora sirunaseva* females posit fusiform eggs in closed capitula of yellow starthistle (Sobhian 1993, Turner in press). In a laboratory cage study conducted in Greece, Sobhian (1993) observed up to 270 oviposited eggs per female, and a mean of 167 oviposited eggs per female. Turner (in press) recorded an average of 136 oviposited eggs per female in a laboratory cage study in California. Lignified, unilocular galls are formed around the developing larvae within capitula. The fly is bivoltine, and overwinters as mature larvae in galls on host capitula. Groppe et al. (1990) and Clement & Sobhian (1991) conducted host specificity tests in field plots in northern

Greece, and Turner (in press) carried out host specificity tests in a quarantine glasshouse. These tests as well as field host records (White & Korneyev 1989) indicate a very high level of host specificity and safety for *U. sirunaseva* as a biological control agent for yellow starthistle.

FIELD RELEASES AND ESTABLISHMENT

The first field releases of *U. sirunaseva* in North America occurred in 1984, when flies imported from Greece were released in California, and flies imported from Turkey were released in Idaho (Turner et al. in press). In 1985, additional releases of flies from Greece were made in California, Idaho, Oregon, and Washington. After the 1985 releases, *U. sirunaseva* releases ceased until the taxonomic confusion between *U. sirunaseva* and the closely related and very similar *U. jaculata* Rondani was clarified (Turner et al. in press) by White & Clement (1987) and White & Korneyev (1989). The fly was thought not to have established until populations were discovered in 1989 at each of its only release sites near Loomis, California (1984 and 1985 releases) and Phoenix, Oregon (1985 release). Field releases commenced in 1989 using material imported from Greece, or flies collected from the initial California and Oregon populations.

As of 1992, *U. sirunaseva* was known to be established in California, Oregon, and Washington. The source of all established populations is the Thessaloniki area of northern Greece. *Urophora sirunaseva* larvae in galled yellow starthistle capitula were shipped from Greece, and releases were made with the adults that emerged in the USDA-ARS quarantine facility in Albany, California. A more detailed description of established populations through the 1992 field season follows.

California. — *Urophora sirunaseva* is established at five sites in California: Loomis (Placer Co.), Hornbrook (Siskiyou Co.), Ukiah (Mendocino Co.), Rancho Cordova (Sacramento Co.), and Mankas Corner (Napa Co.). Flies imported from Greece were released at Loomis in 1984 in two separate releases of 142 adults (78 females, 64 males) and 42 adults (21 females, 21 males), and in a 1985 release of 60 adults (30 females, 30 males). It is not certain which of these releases resulted in establishment. The Hornbrook population was founded by flies ($\approx$ 150 females, 200 males) released in 1990 from adults collected at Phoenix, Oregon. Flies (111 females, 165 males) collected from the Phoenix, Oregon population were also released in 1990 at Mankas Corner; in addition, flies (116 females, 192 males, but unquantified mortality due to high ambient temperature at the time of release) from Greece were released in 1991 at Mankas Corner. It is not certain which of these releases resulted in establishment at Mankas Corner. *Urophora sirunaseva* imported from Greece were released as adults (204 females, 168 males) at the Ukiah site in 1990. The Rancho Cordova population was founded by adult flies (225 presumably mated females) released in 1991 that were collected at Loomis.

Oregon. — *Urophora sirunaseva* is established at six sites in Oregon: Phoenix, Brownsboro, and Black Butte (Jackson Co.); Myrtle Creek and Riddle (Douglas Co.); and East Grants Pass (Josephine Co.). Flies imported from Greece were released (100 females, 100 males) in 1985 at Phoenix. All other flies released in Oregon originated from this population. Flies were released in 1989 at Myrtle Creek (75 females, 50 males) and at Riddle (75 females, 50 males). Flies (250 adults) were released at Riddle again in 1990 as well as at Brownsboro (100 adults).

In 1991, *U. sirunaseva* was released at Black Butte (100 adults) and at East Grants Pass (100 adults). Where the gender ratio is not specified, it was estimated to be $\approx 1:1$.

Washington.—*Urophora sirunaseva* is established at Colfax (Whitman Co.). This population originated from 400 adults (200 females, 200 males) collected from Phoenix, Oregon and released in 1990.

Further field releases of *U. sirunaseva* collected from domestically established populations are planned in the United States. Our redistribution experience thus far has shown that establishment can readily result from releases of either first or second generation adults, and from releases of relatively small numbers of flies (< 100 females).

MATERIALS AND METHODS

A quantitative sampling study was undertaken to assess the status of established field populations of *U. sirunaseva* in California and Oregon. Sampling began in 1989 at the Loomis, California and Phoenix, Oregon populations; and in 1992 at the Hornbrook, California and Ukiah, California populations.

Except for the Ukiah population, sampling was carried out along eight major lines (N, NE, E, SE, S, SW, W, NW) established from a central stake at each release site. Ten samples of whole plants or branches of large plants were taken at random intervals generated by a hand calculator along each line. This sampling method concentrates the sample points in the central area around the release site within a population. The Ukiah population is an elongated patch of yellow starthistle distributed along a steep, narrow hillside. Sampling here was carried out along two lines parallel to the length of the hillside, with samples taken at 40 random points along each line. All sampled capitula were dissected in the laboratory, and counts of *U. sirunaseva* galls were made. All samples were taken in late summer/early fall, thus galls from both generations were counted.

RESULTS AND DISCUSSION

Thus far, there are similar values for percentage galled capitula and number of galls per galled capitulum among three of the populations (Table 1). The percentage of galled capitula at the Ukiah population is approximately twice that of the other populations. The Ukiah yellow starthistle population is somewhat isolated from other host populations in the surrounding area by urban development, whereas the other infested *C. solstitialis* populations that were sampled are essentially continuous with surrounding areas occupied by the weed. Thus the flies may be more readily spreading throughout the surrounding area at Loomis, Hornbrook, and Phoenix, which would dilute fly density and reduce the percentage of infested capitula at any one sample area. Flies have been detected in Medford, Oregon, a distance of ≈ 10 km from the Phoenix release site, and in Newcastle, California, a distance of ≈ 10 km from the Loomis release site. *Urophora sirunaseva* was found in Yreka, California in 1993, a distance of ≈ 21 km from Hornbrook within three years of its release there. This degree of dispersal is encouraging from a biological control viewpoint.

All four populations sampled had a mean of approximately two galls per galled

Table 1. Infestation of yellow starthistle capitula by *Urophora sirunaseva*, 1989–1992.

	1989	1990	1991	1992
Loomis, CA ^a				
% Galled capitula	1.1	11.7	21.5	22.1
(No. capitula sampled)	(417)	(382)	(1716)	(483)
Mean ± SEM galls per galled capitulum	1.0 ± 0.0	1.6 ± 0.1	2.3 ± 0.1	2.1 ± 0.1
(No. galled capitula sampled)	(5)	(45)	(370)	(107)
Maximum no. galls per galled capitulum	1	4	10	7
Phoenix, OR ^b				
% Galled capitula	2.2	18.1	19.6	22.9
(No. capitula sampled)	(311)	(253)	(265)	(353)
Mean ± SEM galls per galled capitulum	1.4 ± 0.2	1.7 ± 0.1	1.8 ± 0.1	1.8 ± 0.1
(No. galled capitula sampled)	(7)	(46)	(52)	(81)
Maximum no. galls per galled capitulum	3	5	6	7
Hornbrook, CA ^c				
% Galled capitula				23.7
(No. capitula sampled)				(270)
Mean ± SEM galls per galled capitulum				2.1 ± 0.1
(No. galled capitula sampled)				(64)
Maximum no. galls per galled capitulum				6
Ukiah, CA ^c				
% Galled capitula				44.0
(No. capitula sampled)				(724)
Mean ± SEM galls per galled capitulum				1.9 ± 0.1
(No. galled capitula sampled)				(319)
Maximum no. galls per galled capitulum				7

^a Field released 1984 and 1985.
^b Field released in 1985.
^c Field released in 1990.

capitulum in 1992 despite galled capitula of < 25% at three out of four locations (Table 1). Figure 1 shows the frequency distribution of galls per galled head for these populations in 1992. More than half of the galled capitula at each site had two or more galls. The distribution of galls per galled capitulum from field populations is quite similar to that obtained during host specificity testing of the fly in quarantine glasshouse studies (Turner in press), and may indicate a tendency towards aggregation, i.e., capitula infested by multiple larvae. This could be important from a control standpoint, as due to the modest size of a single gall, infestation by multiple larvae appears to be necessary to destroy a meaningful percentage of seeds (Turner, unpublished data).

The maximum number of galls per capitulum observed in field populations of the fly is nine in northern Greece (Sobhian, unpublished data); in a separate sample of 215 capitula for a seed destruction study in 1992, we recorded 12 galls in a capitulum at Loomis. We do not know with certainty whether multiple galls in a capitulum originate from one or more females. However, dissected capitula can reveal multiple eggs grouped together indicating that they originate from a single female in at least some instances. Over time we would expect an increase both in percentage galled capitula and in galls per galled capitulum, which is evident

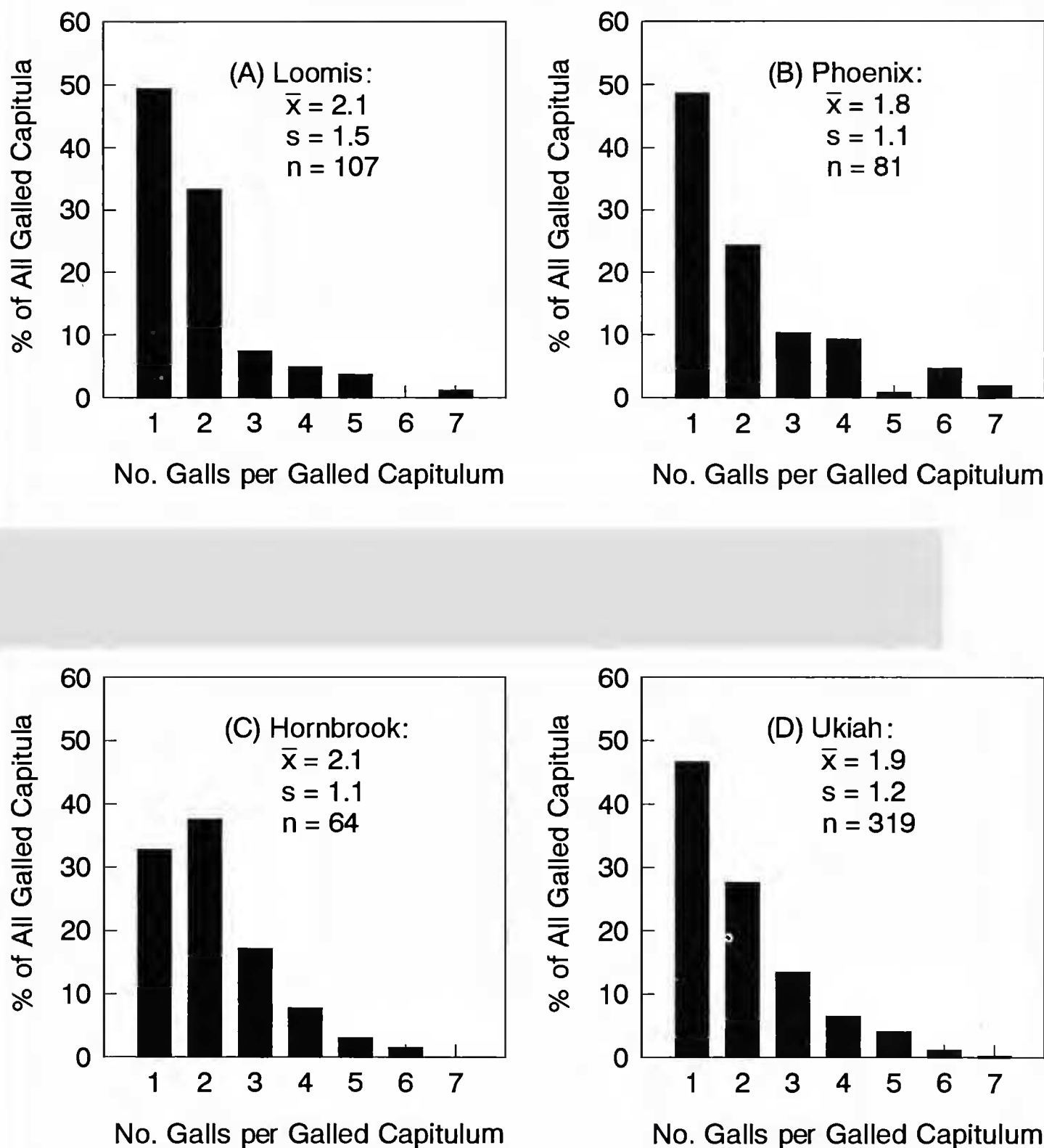


Figure 1. Number of *Urophora sirunaseva* galls per galled yellow starthistle capitulum in 1992 at (A) Loomis, California, (B) Phoenix, Oregon, (C) Hornbrook, California, (D) Ukiah, California.

at the Loomis and Phoenix populations (Table 1). Both types of increase should be necessary to significantly reduce seed production by yellow starthistle.

Urophora sirunaseva is presently one of five capitulum-attacking insects from Greece established in the western United States for biological control of yellow starthistle (Turner et al. in press). The other established species are the weevils *Bangasternus orientalis* (Capiomont), *Eustenopus villosus* (Boheman), and *Larinus curtus* Hochhut, and the tephritid fly *Chaetorellia australis* Hering (Turner et al. in press). The entire course of capitulum development (from the very early closed bud stage to flowering) in yellow starthistle is covered by the timing of oviposition among these five insect species (Turner et al. in press), which provides some basis for optimism in terms of the combined biological control potential of these insects.

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